Examining the Relationship Between Age and Instrument Cluster Design Preference

by

Brian Patrick Weiss

A thesis submitted in partial fulfillment
of the requirements of the degree of
Master of Science in Engineering
(Industrial and Systems Engineering)
In the University of Michigan-Dearborn
2017

Master's Thesis Committee:

Assistant Professor Bochen Jia, Chair
Professor Armen Zakarian
Associate Professor Bruce Maxim
Lecturer Thomas Steiner

Acknowledgements

This thesis would not have been possible without the guidance and consistent help of many different individuals who were instrumental in the completion of this project, as well as providing me with personal support.
I would like to extend my deepest appreciation to Dr. Sang-Hwan Kim. His mentorship led me to foster an understanding of human factors from both a professional and an academic perspective.
I would like to express sincere appreciation to Dr. Bochen Jia. Dr. Jia has provided me an opportunity to develop my technical writing skills through this project.
I am also very grateful to all of my fellow lab mates over the years, specifically Mengyao Xu, Deependra Phatak and Ravi Teja Nadalla. Each one of them has offered support throughout the course of this project, and without them, this thesis would not have come to fruition.
I owe a great amount of gratitude to my family, who supported me through this program. My mom's initial encouragement to enroll as a graduate student in the department of Industrial and Manufacturing Systems Engineering has led to my discovery and subsequent passion for the field of human factors engineering.
Lastly, I would like to thank Kristie for her persistence in reminding me the value of balance and optimism.

Table of Contents

List of Tables

List of Figures

Figure

List of Appendices

Appendix

Abstract

Previous research has indicated that elderly drivers, those aged 65 years and older, find current in-vehicle technology, specifically instrument cluster panel difficult to use. Existing research has determined the source of this discomfort stems from a misalignment between contemporary designs and the designs most usable for elderly drivers. Researchers believe that cognitive ability, which is negatively correlated with age, reduces the driver’s ability to retrieve information from complex instrument cluster designs. The purpose of this study was to evaluate how young (20 to 30 years old) and elderly drivers (65 years old and above) interacted with novel instrument cluster designs, based on how the designs facilitated information retrieval during driving. 50 participants (gender balanced) completed a series of simulated driving tasks to retrieve information from the instrument cluster while driving on two road conditions (city and highway) during a simulated driving. Analysis of variance was used to determine whether designed instrument cluster panels facilitated reading performance, which was measured in the amount of seconds it took participants to retrieve information from the instrument cluster. Additionally, analysis of variance was used to evaluate whether age significantly affected user satisfaction. Our results indicated that designed instrument clusters did not facilitate meter reading for elderly drivers, nor did they elicit higher user satisfaction scores. Age significantly impacted response time. Further analysis also revealed that response time improved in later stages of the experiment, possibly related to the participant learning how to use the driving simulator over the course of the experiment. Future studies could use a longitudinal experiment to minimize the potential learning effect found in this experiment. This study indicated that there should not be novel instrument cluster designs for elderly drivers.

Chapter 1 Introduction

Background

Over the last 30 years, automotive manufacturers have implemented new and innovative technology, such as the graphical driver information systems, and the Advanced Driver-Assistance System (ADAS), into new vehicle models. One particular component of the vehicle that has undergone rapid transformation is the instrument cluster, which is the area behind the steering wheel that contains information on current speed, fuel level, gear, as well as providing any warning indicators to alert the driver that a component of the vehicle has an issue with it. The goal of these technological enhancements are to assist drivers by reducing the demands of critical information processing while driving, thus allowing drivers to pay more attention to primary driving tasks (Akamatsu et al., 2013). A study reviewing the perceptions of elderly drivers towards instrument clusters found that they view such technology negatively because it distracts the driver. Another common point from these focus groups revealed that elderly drivers articulated distain for the poor design of intelligent information transportation systems (Caird, 2004). A study has revealed that elderly drivers continue to hold negative views regarding in-vehicle technology, citing it as distracting to their ability to drive and detracts from safety of the driving experience (Zhan, et al., 2013).

Increasingly, more and more technology become available to leverage the driving experience; concurrently, a greater proportion of the United States population is becoming 65 years and older. U.S. Census data (2013) revealed that the proportion of 45-64 year olds and

65 years and grew over the last decade by 31.5 and 15.1 percent, respectively. Further projections by the U.S. Census Bureau (2015) revealed that the proportion of the US population aged 65 and above is expected to increase substantially over the next fifteen years. A meta-analysis of studies examining association between mobility and age revealed that elderly adults view mobility as vital to their wellbeing, and that driving enables them to achieve basic functionality in life (Goins et al., 2015). Accordingly, automotive manufacturers are seeking how to alter their product to meet the needs of an increasingly aging population (Kim et al., 2014).

Technological enhancements to in-vehicle components have not incorporated the needs and capabilities of elderly drivers, as evident by poor evaluation results by elderly drivers. For instance, an existing study demonstrated that elderly people aged 65 to 85 generally have a difficult time understanding how to use an early in-vehicle navigation system while driving (Barham et al., 1995). A more recent study interviewed focus groups of elderly drivers who use in-vehicle navigation systems at least once a month. Results from that study revealed that elderly drivers considered those systems difficult to learn, and that the screen was difficult to retrieve information from (Emmerson et al., 2013). Development of an in-vehicle technology system, which facilitates information retrieval for elderly drivers, must take into account the capabilities and needs of the elderly drivers.

In order to enhance the usability of instrument cluster for elderly drivers, car companies and researchers alike study what designs of the instrument cluster facilitate instrument cluster design, for younger and elderly drivers. For instance, existing research found that novel instrument clusters, which featured larger font and gages, elicited higher user satisfaction in interviews (Havins, 2011). Subsequent studies have examined what elderly drivers expect in their instrument cluster by asking elderly and young drivers to develop their own instrument cluster using paper-based prototypes. Results from these studies revealed that elderly users preferred simpler designs with a larger font size, and also revealed the design and location preferences for the speedometer, gas meter, and the warning icons, such as putting the right justifying the speedometer to reduce head movement. As compared to contemporary designs of instrument clusters, the prototype designed by elderly drivers was found to be much simpler than the prototypes designed by young drivers, with a stronger emphasis on ease of use (Kim et al., 2014, 2016). A follow-up study was conducted to evaluate whether or not the simple prototypes designed by the elderly drivers actually resulted in higher satisfaction, and facilitated driving more than the contemporary design of the instrument cluster in a driving experience. The simply designed instrument clusters were found to have higher satisfaction rates among elder drivers, who drove using a computer-based vehicle simulator (Kim et al., 2014). Previous research also indicates that highway driving leads elderly drivers to have more long glances, that is glances away from the road for longer than two seconds, and increased time spent not looking at the road, while retrieving information from information gages (Wikman et al., 2005). Likewise, other research has indicated that rain-simulated weather increases elderly participants' response time while completing secondary driving tasks (Konstantopoulos et al., 2010).

Even though existing studies indicated that elderly drivers have higher satisfaction while using simple instrument clusters, it is unclear whether these instrument cluster designs will facilitate secondary driving tasks, such as reading, while driving in different road conditions, such as city or freeway. Furthermore, it is unknown how driver's characteristics (i.e., age and gender) will impact secondary driving tasks with these specific instrument cluster designs. Therefore, the goal of this study is to evaluate how elderly and young drivers use a previously developed instrument cluster (Kim et al., 2014) to complete secondary driving tasks in different driving conditions. Additionally, this will provide researchers with sufficient data as to determine whether the instrument cluster helps secondary tasks while driving in different condition.

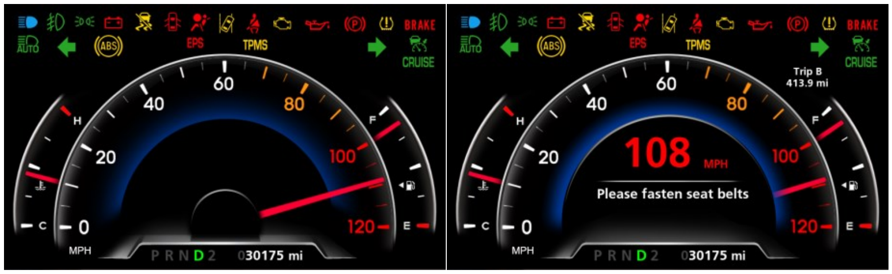
Chapter 2 Methods

Participants

Fifty participants were recruited from the university and surrounding community. Participants were divided into two age groups: 30 elderly participants [(i.e., ≥ 65 years), mean (SD) = 69.8 (4.0)], and 20 young participants [(i.e., 20-30 years, mean (SD) = 22.8 (2.8)]. Both age groups were gender balanced. All participants had to have a valid US driver's license with a minimum of 5 years driving experiences, be fluent in English, and have lived in the United States for the past 10 years to ensure that they were used to road conditions in the United States.

Experimental Design

The independent variables included two age conditions (young and old), two driving conditions (city driving under foggy weather conditions and highway driving under clear weather conditions), gender, and four instrument clusters designs with various levels of complexity. Cluster design one and two contained minimal required information designed according to the expectations of elderly drivers (Kim, 2016), while cluster design three and four contained extensive information, including a tachometer, in line with the expectations of younger drivers (Kim, 2016). The Dependent Variables included response time measured in milliseconds, and user satisfaction measured via post-trial evaluation. Response time, which was the time a participant took to answer a few pre-developed questions, such as "what's your current speed?" while using the instrument clusters during driving. To measure the response time, a video camera was used to record participants' response time, the time duration of the answer given. The video was later analyzed to attain the response time for each participant. User satisfaction with the instrument cluster was recorded using a 7-question questionnaire in a post-trial evaluation. Questions were rated on a 7-point Likert scale, where 1 indicated 'Strongly Disagree' and 7 indicated 'Strong Agreement'. Each answer was added up to create a single post-trial evaluation score for each participant trial. A high score of 49 indicated that the instrument cluster was evaluated as easy to use. As shown in Figure 1, each of the designs displayed differing amounts of information for the end user: cluster number one displaying the most critical information (speed, engine temperature, and fuel level) without a digital printout for speed; cluster number two had the same design as cluster number one, but contained a digital printout of the vehicle's current speed; cluster design three contained a full circle tachometer, left justified, and a full circle speedometer, right justified; cluster design four contained a full circle speedometer, which was centered in the design, a half circle tachometer, and a right-justified half circle that contained navigation information. The dependent variables in this study included: Response time, which was the time a participant took to answer a few pre-developed questions (listed in Appendix A), such as "what's your current speed? ", while using the instrument clusters during driving?; User satisfaction with the instrument cluster, which was recorded using a post-trial evaluation (PTE) (listed in appendix B).



(1) (2)

(3) (4)

Figure 1. The four instrument clusters used in the experiment (1→4: simple→complex)

Upon the completion of experiment, the participants were also asked to complete a post-experiment interview, which consisted of open-ended questions about each cluster and components of the cluster. The interview allowed for participants to offer extensive feedback about their driving experience using the instrument cluster.

Driving Simulator

A high-fidelity driving simulator developed by SimCreator (Royal Oak, MI.) was used to simulate two driving conditions. The driving simulator contains a vehicle setup, which had break and acceleration pedals and a steering wheel. The pedals were designed to be just as sensitive as a normal break and acceleration pedal by responding to the strength of the press down on it. Figure 1 contains a picture of the vehicle simulator setup.

Figure 2. The driving simulator used in the experiment

The simulator had a LCD monitor that was placed on dashboard behind the steering wheel to display the information cluster as a replication of the information cluster setup in most contemporary vehicles. Four fully functional Java-based instrument clusters were developed, each consisting of a speedometer, fuel indicator, and, for two of the designs, a tachometer. The speedometer changed in real-time, based on the participants' driving behavior. All clusters were able to present 4 warning icons (i.e., seatbelt off indicator, battery off, parking break, and lane departure), and 4 headlight icons (i.e., side marker, hi-beam, auto, and low-beam) which were turned on and off by the experimenter at random intervals. The experimenter used the warning and headlight icons to evaluate how participants would respond to simulated occurrences where the instrument cluster delivers critical information.

Experimental Procedure

This study consisted of three parts: pre-experiment demographic questionnaire, simulated driving task, post-trial evaluation, and post-experimental interview. The study took approximately two hours for each participant with a break of a few minutes between each part. Participants were explained the procedure of the experiment and asked to sign an informed consent approved by a local IRB committee. If they agreed to continue on with the experiment, they were asked to complete a demographic questionnaire, which retrieved information on their age, gender, and their driving history. Upon completion of the pre-experiment demographic questionnaire, participants were led into the room with the driving simulator. Participants were then explained how to use the simulator, and then asked to complete a practice trial. If the participant felt comfortable advancing, they were then asked to complete a series of driving tasks contained eight scenarios [2 road condition (city vs. freeway) x 4 cluster designs] while maintaining the speed limit (40 miles per hour for the city simulation, and 65 for the highway simulation), lane position, and at least one vehicle's distance away from the vehicle ahead of them. During each scenario, participants were asked to complete a series of 4 questions regarding retrieving information from the instrument cluster, such as their current speed and what type of warning icon was on. The order of cluster and road combination as well as questions, were randomized to prevent any order related effect. After each scenario, the participant was asked to complete a post-trial evaluation, which asked questions related to the usability of the instrument cluster. Once all 8 scenarios were completed, the participants then completed a post-experiment interview. In total, the procedure took each participant approximately two hours to complete.

Data Analysis

A repeated measures ANOVA was used to identify the main and interactive effects of instrument cluster design, gender, road conditions, and drivers' age on post-trial evaluation. The analysis was conducted to evaluate whether or not the cluster design, age, road condition, gender, or first-level interactions among these four factors significantly affected how subjects subjectively evaluated the drivers' response time. Additionally, the impact of instrument cluster design, road condition, age and gender on drivers' response time was also analyzed using repeated measures ANOVA. In both cases, when significant results were found in the ANOVA, a pairwise analysis was conducted to determine which groups significantly differed from each other. Data Analysis was conducted using R and SAS Studio.

Chapter 3 Results

Response Time

The mean and standard deviations of response time by age group, gender, cluster design, and road condition can be found in Table 1.

Table 1. Means and Standard Deviations of Response Time (in milliseconds) by Age Group, Cluster Design, Road Condition, and Gender.

	Old				Young			
	Male		Female		Male		Female	
	Road	Highway	Road	Highway	Road	Highway	Road	Highway
Instrument Cluster One	7856.9 (2523.7)	8505.4 (2460.4)	8744.7 (3136.0)	8674.6 (2443.1)	5612.7 (1185.2)	5984.4 (1216.4)	6668.9 (2209.6)	6706.7 (1911.0)
Instrument Cluster Two	8784.0 (4810.9)	9983.9 (10897.0)	9659.3 (4527.1)	6930.7 (2622.0)	5701.1 (671.0)	5679.1 (1559.9)	6752.5 (2356.9)	6545.0 (2213.5)
Instrument Cluster Three	10835.7 (6746.8)	7573.9 (2375.5)	9357.9 (3079.3)	8835.7 (2916.6)	5152.2 (1104.3)	6277.3 (1671.3)	6541.1 (2574.1)	11860.0 (15769.8)
Instrument Cluster Four	6820.0 (2619.7)	7420.0 (2225.2)	8263.3 (2508.6)	7725.3 (2855.0)	8821.8 (9863.3)	5422.2 (1782.0)	7544.4 (3124.0)	6284.4 (1741.5)

A two-way ANOVA was conducted to compare the effect of instrument cluster design, age, gender, and road condition, on response time. Results revealed age had a significant effect on response time $F\,(21) = 13.47$, $p < .001$. Subsequent pairwise comparison analysis revealed that elderly participants had a higher response time than younger participants ($p <$. 004). Further analysis revealed that gender and cluster design did not have a significant effect on response time. Table 2 shows the results of the analysis. As shown in Table 1, the response time of elderly males using cluster 3 was significantly larger than the response time of younger males.

Table 2. Effect of Cluster Design, Age Group, Gender, and Road Condition on Response Time

Effect	*MS*	*df*	*F*	*p*
Cluster Design	21312103	3	1.02	0.38
Gender	31133834	1	1.49	0.22
Age Group	280744231	1	13.47	**<.001**
Road Condition	9532700	3	0.46	0.49
Cluster Design* Age Group		3	1.00	0.39
Cluster Design* Gender		3	0.45	0.72
Age Group* Gender		1	1.53	0.80
Cluster Design*Road Condition		3	0.36	0.86
Road Condition* Age Group		1	0.62	0.44
Gender*Road Condition		1	0.03	0.87
Residual	20843973	340		

Post-Trial Evaluation

The mean and standard deviations of post-trial evaluation scores by age group, gender, cluster design, and road condition can be found in Table 3.

Table 3. Mean and Standard Deviation of Post-Trial Evaluation Score by Age Group, Cluster Design, Road Condition, and Gender.

	Old				Young			
	Male		Female		Male		Female	
	Road	Highway	Road	Highway	Road	Highway	Road	Highway
Instrument Cluster One	34.6 (6.0)	37.2 (5.7)	36.9 (8.4)	39.5 (6.1)	33.6 (6.6)	38.2 (4.0)	39.8 (5.9)	38.3 (5.4)
Instrument Cluster Two	36.5 (6.4)	36.6 (8.8)	36.5 (5.4)	37.3 (7.4)	33.4 (4.0)	35.5 (4.2)	34.9 (4.3)	39.6 (5.5)
Instrument Cluster Three	35.9 (4.4)	36.3 (6.6)	34.9 (5.7)	36.5 (6.9)	34.7 (4.6)	32. 7 (4.2)	36.9 (7.6)	38.9 (4.5)
Instrument Cluster Four	34.4 (8.8)	35.6 (6.5)	35.8 (8.4)	37.1 (7.4)	34.3 (5.0)	34.6 (5.7)	36.6 (7.8)	40.3 (5.5)

An *ANOVA* was conducted to compare the effect of instrument cluster design and age on user satisfaction. Results revealed that age had no significant effect on user satisfaction $F\ (1,3) = 0.001$, $p = .95$. Similarly, cluster design had no significant effect on post-trial evolution scores. However, gender did significantly impact how participants evaluated instrument cluster designs $F\ (1,3) = 9.5$, $p = <0.01$. Likewise, road condition also significantly impacted post-trial evaluation scores $F\ (3,3) = 5.02$, $p = 0.03$ as shown in Table 4.

Table 4. Effect of age group, cluster design, road condition, and gender on post-trial evaluation

Effect	*MS*	*df*	*F*	*p*
Age	0	1	0.001	0.95
Gender	388.1	1	9.5	**<0.01**
Road Condition	205.1	1	5.02	**0.03**
Cluster Design	31.2	3	0.76	0.51
Age Group* Gender	181	1	5.02	0.03
Age Group* Cluster Design	10	3	0.245	0.85
Age Group* Road Condition	4.7	1	0.11	0.73
Gender* Road Condition	13	1	0.32	0.57
Cluster Design * Road Condition	10.3	3	0.25	0.86
Age Group*Gender* Cluster Design	13.8	3	0.34	0.79
Age Group*Gender* Road Condition	1.2	1	0.03	0.86
Residual	40.9	368		

Chapter 4 Discussion

The goal of this study was to evaluate distinct instrument cluster designs under different driving conditions to determine if certain designs facilitated instrument cluster reading while driving, measured through a low response time, or elicited higher feedback, as measured through the post-trial evaluation. The significant results of this study have shown a difference in reading performance between the elder and younger age group, with younger drivers taking the least amount of time retrieving information from instrument cluster design 2, and older participants taking the least time to retrieve information from instrument cluster design 4. This finding contrasts the previous research conducted by Kim et al., (2014, 2016), which found that elder participants preferred simple designs, similar to design of instrument cluster 2, as opposed to the design of instrument cluster 4. Likewise, the same prior research indicated that younger drivers previously preferred the more complex instrument cluster designs, similar to instrument cluster 4. There are several reasons why these were the results observed. For instance, the participants from this study could have been more comfortable using technology while using the driving simulator than the participants of previous studies looking at the same instrument cluster designs (e.g., Kim et al., 2014, 2016), thus shortening their response time. Another source of possible source of variation between the previous studies and the current study was the simulator used. The previous study used a conceptual prototype, where the instrument cluster was displayed on a computer monitor. This study, utilized a simulator fitted to resemble the interior of a simulated vehicle. Most notably, elderly participants driving a motion-based driving simulator are more likely to have motion sickness than younger drivers (Domeyer et al., 2013). Motion sickness attributable to the fix-based driving simulator could explain the significant difference in response time between younger and elderly drivers. Moreover, the experience of using the instrument cluster in a realistic driving experience could reveal different preferences than stated ratings. The more authentic driving experience serves as one possible explanation to the difference between this research and previous research. This hypothesis is supported by findings from a report published by Philips and Morton (2015), which found that the more realistic driving simulators produced more valid results, when compared to actual driving behavior from the same participants in similar driving conditions.

The stated ratings, measured by the post-trial evaluation, had different results than the results from the conceptual prototype evaluated by our previous studies (Kim et al., 2014, 2016), which indicated a significant difference in preference between young and elderly drivers. This, however, was not noticed in post-trial evaluation scores. Most notable was the sex difference observed in the post-trial evaluation; Females generally rated the instrument cluster more favorably than male participants across all experimental contexts, with no effect from age. Females did not have a significantly different response time than males, however. These results fall in line with Roberts et al., (2014), which found distinctions in the way that female participants tended to evaluate technology more favorably.

Cluster design did not have a significant impact on response time or post-trial evaluation scores in this experiment. This finding was not in line with previous research (Kim et al., 2011), which found that elderly drivers performed secondary-driving tasks worse than younger drivers when using a cluttered cluster to complete the secondary task. The differences could also due to the different driving experience using different driving simulators. In addition, this study strictly used visual modality to deliver information present in the instrument cluster (i.e., current speed, current fuel level, etc.,). Alternatively, cluster design could utilize audio-based information delivery. Previous research found that elderly drivers prefer information retrieval from their in-vehicle transportation system through auditory modal delivery (Emmerson et al., 2013).

Besides the findings, this study had limitations, which prevented some inferences from being drawn from the results. For instance, the two test road conditions were a combination of both weather and driving conditions, i.e., the city condition represented a low speed driving under rain and fog, while the highway condition represented a high-speed driving featured clear and sunny weather conditions. Future studies could examine the impact of weather on instrument cluster preference by randomizing the weather condition to each trial. Additionally, even though the simulator used in current study is much better than previous studies, research completed by the U.S Department of Transportation Federal Highway Administration (2015) noted that more realistic driving simulators produced driving behavior more vindictive of actual driving behavior, the research also noted that there still was a discrepancy between subjects' simulated driving and actual driving. The location of this experiment, a laboratory, could have impacted the results of the study by causing people to drive differently than they actually would. Future studies could replicate this study using an actual vehicle being driven on the road. This would not only reduce the potential impact of a laboratory environment on driving behavior, but this would also allow the experiment to measure actual driving behavior. Lastly, drivers were also to repeated several similar test conditions, which may have led to an effect on response time attributable to the learning effect. The first trial took significantly had higher response times than the last trial, leading to a large amount of variability within each participant's total, or summated, response time. To better control for the learning effect, a future study could use an alternative design, such as spreading the trial up over the course of two days. Breaking up the experiment over the course of two days, with an equal number of trials on both days, could enhance participant's comfort with using the driving simulator and reduce participant fatigue. Previous research on how to reduce or eliminate simulator sickness in elderly participants also found that using a two-day delay between simulator evaluation periods significantly reduced motion sickness, which allowed elderly participants to more comfortably drive the driving simulator   Domeyer et al., (2013). Adopting this methodology may reduce the confounding variables of fatigue and simulator sickness, and give the experimenter more valid user evaluation results.

In conclusion, this study's task was to evaluate four different instrument cluster designs by different individuals of different age and gender. This study found that different cluster designs help facilitate the information retrieval process, which has serious implications for how the driver is able to complete secondary tasks while driving. Additionally, this experiment continued to allow individuals to comment on how to improve the current instrument cluster designs, which will allow for further improvement of the cluster designs used in this experiment.

References

Akamatsu, M., Green, P., & Bengler, K. (2013). Automotive technology and human factors research: Past, present, and future. *International Journal of Vehicular Technology,* 1-27.

Barham P. A. J., Oxley, P. R., Ayala, B. E., & Alexander, J. J. (1995*). Proceedings from the IEE Colloquium on Design of Driver Interface*: The ergonomic and safety implications of in car ATT devices-evidence from field trials with elderly drivers. UK: London.

Caird, J. K. (2004). *Transportation in an Aging Society: A Decade of Experience, technical papers and reports from a conference, November 7-9, 1999,*: In-vehicle intelligent transportation systems: Safety and mobility of older drivers. Washington, D.C.

Domeyer, J. E., Cassavaugh, N. D., & Backs, R. W. (2013). The use of adaptation to reduce simulator sickness in driving assessment and research. *Accident Analysis and Prevention*, 127-132.

Emmerson, C., Guo, W., Blythe, P., Namdeo, A., & Edwards, S. (2013). Fork in the road: In vehicle transportation systems and older drivers," *Transportation Research Part F,* Vol. 21*,* 173-180.

Havins, W. H. (2011). *Application of Human Factors and Cognitive Neuroscience Principles in the Design of Vehicle Information Displays* (No. 2011-01-2256). Retrieved from http://papers.sae.org/2011-01-2256/

Kim S., Dey A. K., Lee, J., & Forlizzi, J. (2011*). Proceedings from the ACM CHI '11*: Usability of car dashboard displays for elderly drivers. BC: Vancouver.

Kim S., Xu, M., Harrelson, H., Kinshu Askay Pedamllu, R., Weiss, B., & Escobar, C. (2014). *Proceedings from the Human Factors and Ergonomics Society 58th annual meeting*: Examining relations of driver's self-confidence level with automotive instrument cluster reading performance. IL: Chicago.

Konstantopoulos, P., Chapman, P., & Crundall, D. (2010). Driver's visual attention as a function of driving experience and visibility. Using a driving simulator to explore drivers' eye movements in day, night and rain driving. *Accident Analysis & Prevention, 42,* 827-834.

Philips, B., & Morton, T., (2015). *Making driver simulations more useful for behavioral research: Simulator characteristics comparisons and model-based transformations*. McLean, VA: U.S. Department of Transportation Federal Highway Administration.

Roberts, S. C., Mehler, B., Orszulak, J., Reimer, B., Coughlin, J. & Glass, J. (2011). Proceedings from 2011 Industrial Engineering Research Conference: *An evaluation of age, gender, and technology use in user performance and impressions of a multimodal human machine interface.*

U.S. Census Bureau. (2013). The Older Population: 2010, http://www.census.gov/prod/cen2010/briefs/c2010br09.pdf, 2011.

U.S. Census Bureau. (2015). Projections of the Size and Composition of the U.S. Population: 2014 to 2060. Retrieved from: https://www.census.gov/content/dam/Census/library/publications/2015/demo/p25 1143.pdf

Wikman, A., & Summala, H. (2005). Aging and time-sharing in highway driving. Optometry & Vision Science, 82, 716-723.

Zhan, J., Porter, M. M., Polgar, J., & Vrkljan, B. (2003). Older drivers opinions of criteria that informs the cars that they buy: A focus study. *Accident Analysis and Prevention, 61,* 281-287.

Appendix A

Questions Asked During the Experimental Trial

What is your current speed?

What is your fuel level?

What is the light icon on right now?

What warning icon is on right now?

Appendix B

Post-Trial Evaluation

Please answer the following questions regarding your experience throughout each experiment trial.

No.	Questions	**Strongly Disagree**						**Strongly Agree**
		1	2	3	4	5	6	7
1	I was able to quickly get the information I was looking for							
2	The information was located where I expected it to be in the instrument cluster							
3	I thought the instrument cluster was very easy to read							
4	The size and text were easy to read							
5	The instrument cluster had too much information, which required too much attention and thought							
6	The instrument cluster had all the information I desired							
7	I prefer the instrument cluster							

Appendix C

Demographic Questionnaire

For the purpose of our study, we would like to gather some basic information about your memory, activities, driving experience, and current vehicle ownership. Please answer the following information as accurately as possible. Thank you.

GENERAL INFORMATION:

Age: ____
Gender: _________________________

Do you currently live alone? ☐Yes ☐No
If No, with whom do you live? ____

How many years have you been driving? _______________ years

Approximately how many miles do you drive on a daily basis? _____________ miles

While driving, do you use a GPS (navigation) system? ☐Yes ☐No
If Yes, how often do you use it? ____

While driving, do you use your cell phone or other mobile devices? ☐Yes ☐No
If Yes, how often do you use it? ____

While driving, do you use a backup camera? ☐Yes ☐No ☐N/A
If Yes, how often do you use it? ____

Do you wear glasses? ☐Yes ☐No
If Yes, please indicate why you wear glasses:
☐Reading ☐Driving ☐Always

Please tell us about some information about your current vehicle:

Year:________________________ Make:__________________________

Model:____

Length of Ownership (in years): ___________________________

Appendix D

Post-Experiment Interview

Please answer the following questions regarding your experience throughout each experiment trial.

Shape of Speedometer

- Design one and two has rainbow (half-circle) speedometers and three and four have circle shaped speedometer. Which style do you prefer between them? Why or why not?
- Does size of text affect your preference?
- Any other suggestions on speedometer design?

Utility and Preference of Digital Readout & Needle Gauge

- In the first design (P1), there is no numerical value for speed given while others (P2, P3, & P4) include digital Readout. Do you prefer this? Why??
- In the experiment, when you were asked to read "current speed", which information did you put attention between needle and digital readout?
- Then, when you were asked to estimate "speed deviation from speed limit", which information did you put attention. Tell me more your detailed procedure to estimate them

Location of Speedometer

- Design three has a speedometer, which is off center (right side). Do you prefer this? Why or why not?
- Among left, center, and right side, which side do you prefer to have speedometer? Why?

Utility of Color Coding in Speedometer and Tachometer

- Do you find the color feature of the speedometer and tachometer useful? Why or why not?
- Have you noticed the color changes in speedometer and tachometer in the last experiment trials?

Utility and Location of Tachometer

- The tachometer is presented in the third and forth design. Do you use the Tachometer in your regular driving? If so, do you prefer the full circle design found in 3 or the half circle design in 4? Why?
- Any other design suggestions on the tachometer?

Shape of Fuel Gauge

- Do you prefer the gas level meter in design one and two or the gas level meter in design three and four? Why?

- Any other design suggestions on the fuel gauges and engine temperature?

Shape of Gear Indicator

- P1, P2 and P4 have full size gear indicator while P3 shows only single letter, which style do you prefer? Why?
- Any other design & location suggestions on the gear indicator?

Location & Utility of Message Window

- The message center in P3 is accompanied with a picture. Do you prefer the textual or pictorial representation of the message center? Why?
- What kind of vehicle information do you expect in message center window?

Telltales and Warning

- All four features in this study have identical locations of symbols, especially located upper area in cluster. Do you prefer it? Why or Why not?

More Features

- Do you want to include any other cluster components (e.g., navigation, audio, climate control, etc.,) in your vehicle cluster? What is it? Why?

General Preference

- Among the four cluster features, which one do you most prefer? Why?
- Why not for other feature set?
- Any suggestions on most preferred features?